# Indicators of financial crises do work! An early-warning system for six Asian countries

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**Abstract**

Indicators of financial crisis generally do not have a good track record. This paper presents an early warning system for six countries in Asia, in which indicators do work. We distinguish three types of financial crises, currency crises, banking crises and debt crises, and extract four groups of indicators from the literature—external, financial, domestic (real and public), and global indicators—that are likely to affect the probability of financial crises. The significance of the indicator groups is tested in a multivariate logit model on a panel of six Asian countries for the period 1970:01-2001:12. An additional feature is that we examine four different currency crisis dating definitions. A within-sample signal extraction experiment reveals that some currency crises dating schemes outperform others.

*Keywords:* financial crises, currency crises, banking crises, debt crises, early warning system, panel data, multivariate logit, factor analysis
*JEL-code:* C33, C35, F31, F34, F47

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## 1. Introduction

Four waves of financial crises have hit international capital markets during the 1990s: the European Monetary System (ERM) crisis in 1992-1993, the collapse of the Mexican peso with 'tequila effects' in 1994-1995, the Asian flu of 1997-1998, and the Russia virus in 1998. These financial crises stimulated the theoretical and empirical literature on the economics of the crises in several ways, among other things on the determinants of a crisis (Kaminsky and Reinhart, 1999), its impact on domestic output (Aghion, Bacchetta, and Banerjee, 2001), and policy implications (Rogoff, 1999).

In view of the large costs associated with a financial crisis, the question of how to predict a crisis has become central. This resulted in the construction of a monitoring tool, the so-called *early warning system* (EWS). An EWS consists of a precise definition of a crisis and a mechanism for generating predictions of crises (Edison, 2003). Three varieties of financial crises are distinguished: currency crises, banking crises, and debt crises. Concise definitions are provided in Section 3 below. Several mechanisms have been suggested. The most popular one is to use qualitative response (logit or probit) models. Examples are Frankel and Rose (1996), who study currency crises and Dermirgüç-Kunt and Detragiache (1997, 2000) on banking crises. Alternatives are cross-country regression models with dummy variables as put forward by Sachs, Tornell, and Velasco (1996), graphical event studies as suggested by Eichengreen, Rose, and Wyplosz (1995) and the signal extraction approach, a probabilistic model proposed by Kaminsky, Lizondo and Reinhart (1998) (and recently applied by Subbaraman, Jones and Shiraishi (2003)). In the latter mechanism values of individual indicators are compared between crisis periods and tranquil periods. If the value of an indicator exceeds a threshold, it signals an impending crisis. A common feature of all existing EWS studies is the use of fundamental determinants of the domestic and external sectors as explanatory variables.

This paper develops an econometric EWS for six Asian countries, Malaysia, Indonesia, Philippines, Singapore, South Korea, and Thailand. The Asian flu hit Thailand and spread to other countries—except Singapore—almost instantaneously. We set up qualitative choice models, in our case logit models, for currency crises, banking crises and debt crises with indicators extracted from a broad set of potentially relevant financial crisis indicators.[1] The set-up of our EWS is similar to Kamin, Schindler and Samuel (2001) and Bussiere and Fratzscher (2001), who also adopt a binomial multivariate qualitative response approach. However, while the final result of their (unreported) specification search is combinations of indicators as explanatory variables, we apply factor analysis to reduce the information set and include factors for groups of variables as explanatory variables in our EWS. The models are estimated using panel data for the January 1970–December 2001 period. The factor analysis outcomes in combination with the estimation results allow the general conclusion that (some) indicators of financial crises do work, at least in our EWS of Asia. This finding is in contrast with Edison (2003), who notes that the per-

1. Unfortunately, we cannot adopt the main recommendation of Eichengreen and Portes (1987), *i.e.*, to treat the three categories of crises simultaneously, because among other things the number of crisis observations is too low.

formance of EWS is generally poor and at best mixed. Our method—the combination of factor analysis and logit modeling—enables us to answer the question whether additional indicators have explanatory power for financial crises, as proposed by Bustelo (2000). It also allows us to dismiss uninformative indicators. In particular, we find that the rates of growth of money (M1 and M2), bank deposits, GDP per capita and national savings correlate with all three types of financial crises, whereas the ratio of M2 to foreign reserves, and the growth of foreign reserves, the domestic real interest rate and inflation play an additional role in banking crises and some varieties of currency crises.

An additional feature of our paper is that we distinguish four currency crisis dating definitions.[2] A priori we do not prefer one of these definitions. However, a within-sample signal extraction experiment reveals that the methods of Eichengreen, Rose and Wyplosz and Kaminsky, Lizondo and Reinhard are superior to the dating schemes of Frankel and Rose, and Zhang. An out-of-sample forecasting experiment is included to illustrate the quality of our EWS.

The organization of the paper is as follows. Section 2 reviews the EWS literature focusing on various methods to measure and date currency crises, banking crises and debt crises, and financial crises indicators. Section 3 describes the methodology adopted in this paper to measure financial crises, currency crises, banking crises and debt crises. The results—dummy variables indicating dates of various crises—are summarized in frequency tables which reveal information on the distribution of each type of crises over countries, time and month. The dating dummies are used in binary choice models that explain the probability of crises. Section 4 describes our set of indicators, and presents and discusses our main results, both of the factor analysis and the binomial multivariate logit models for each type of crises and variety of currency crises. Furthermore, we analyze the performance of the models in an in-sample experiment. Section 5 concludes.

## 2. Literature

The list of studies on EWS of financial crises is long and expanding rapidly. A full list is beyond the scope of this paper.[3] Typically, an EWS has an empirical structure with indicators that contribute to a country's vulnerability to a future crisis and forecasts the likelihood of a financial crisis. EWS models differ widely in terms of the definition of financial crisis, the time span on which the EWS is estimated and attempts to forecast, the selection of indicators, and the statistical or econometric method. This section begins with a discussion of how to measure and date financial crises. Thereafter we examine a

2. The literature that focuses on contagion usually dates currency crises on the base of some 'events' like the Russia or the Asia crisis. Examples are Forbes and Rigobon (2002) or Van Rijckeghem and Weder (2001).

3. Interested readers are referred to Kaminsky, Lizondo, and Reinhart (1998) for papers on currency crises prior to the East Asian crisis, and Bustelo (2000) and Burkart and Coudert (2002) on the East Asian crisis; Gonzalez-Hermosillo (1996) and Dermirgüç-Kunt and Detragiache (1997) on banking crises; and Marchesi (2003)'s survey on debt crisis.

selection of empirical studies on financial crisis, focusing on financial crises indicators, the most important issue in the construction of an EWS.

## 2.1 Measuring and dating financial crises

### 2.1.1 Currency crises

Eichengreen, Rose, and Wyplosz (1995, 1996) made an important early effort to develop a method to measure currency pressure and to date currency crises. Their definition of exchange rate pressure is inspired by the monetary model of Girton and Roper (1977). The exchange rate is under pressure if the value of a constructed index exceeds a certain threshold. The index consists of weighted relative changes of the nominal exchange rate, international reserve and interest rates to capture successful as well as unsuccessful speculative attacks. All variables in their index are relative to a reference country and their threshold is time-independent.

The method of Eichengreen *et al.* was heavily criticized which led to alternatives based on the same methodology. Kaminsky, Lizondo and Reinhart (1998) and Kaminsky and Reinhart (1999) followed the concept of Eichengreen *et al.* fairly closely, but they excluded interest rate differentials from their index since interest rates were controlled by central banks in their sample, the 1970s and 1980s, and comparisons to a reference country. In this paper we analyze two other alternatives. The first excludes unsuccessful attacks from the index, since these are hard to detect. Frankel and Rose (1996)—and Esquivel and Larrain (1998)—drop international reserves and interest rates differentials from the exchange rate pressure index and construct a currency crash index. The second takes the volatility of variables in the currency crisis explicitly into account. Zhang (2001) defines time-dependent thresholds to handle this problem.

### 2.1.2 Banking crises

The definition of banking crises is less precise than the definition of a currency crisis and hence more difficult to implement. Recent studies on banking crises show important differences regarding crisis episodes. The most-cited studies for dating banking crises are the following:

- Caprio and Klingebiel (1996) start from a sample of 69 countries for which information on bank insolvencies is available since the mid-1970s to 1998. An episode of a systemic banking crisis is identified if a country experiences an erosion of bank capital and estimated costs of resolving the crisis are high. Their data is based on published sources and interviews with country economists.
- Lindgren, Garcia and Saal (1996) draw a distinction between banking crisis (systemic episodes) and banking problems, defined as ”significant extensive unsoundness short of crisis” (localized crises or non-systemic episodes). Banking crisis refer to evidence of bank runs or other substantial portfolio reallocations, collapsing

financial firms, or massive government intervention. Their list of banking problems includes episodes from 1980 to mid-1996 and covers 181 IMF-member countries.

- Dermirgüç-Kunt and Detragiache (1997) define a banking crisis as an episode of banking distress in which the ratio of non-performing assets to total bank assets exceeds 10 percent and the costs of rescue operations exceed 2 percent of GDP. Banking crises are also frequently identified by events such as bank failure, large scale bank nationalization, deposit freezes, prolonged bank holidays and bank shutdowns or mergers. They use a sample of 65 countries from 1980 to 1995.
- Kaminsky and Reinhart (1999) mark the start of banking crises by events that point at (i) bank runs that lead to closure, merger or takeovers by the public sector of one or more financial institutions, or (ii) a large-scale government bail-out of one or more financial institutions that is followed by more bail-outs. A banking crisis ends when government assistance stops. Their sample has 20 countries for the period of 1970-1995.

The first three studies specify both the beginning and the end of crises on an annual basis, but Kaminsky and Reinhart (1998) list the start of the crisis at a monthly frequency. All of these studies register events for crisis dates, except Dermirgüç-Kunt and Detragiache (1997) who try to include quantitative measures. However, some measurement problems exist. First, central bank quasi-fiscal operations for rescue purposes are difficult to quantify. In some respects, this is simply because central bank accounting conventions differ from those of government and the distinction between monetary and fiscal activities of the central bank is blurred. Secondly, the main banking problems observed in recent years do not stem from the liabilities side of bank balance sheets. Since the introduction of deposit insurance, it is no longer possible to date a banking crisis on the basis of changes in bank deposits. As banking crises generally arise from the assets side of banks' balance sheets, indicators such as changes in prices in the real estate sector and non-performing assets are becoming more and more important. Unfortunately, both indicators are not available in a timely manner.

### 2.1.3 Debt crises

Since the onset of debt crises in the 1980s and 1990s, an extensive theoretical and empirical literature has dealt with the determinants of sovereign default and sovereign risk. All of these studies have in common that they start from a definition of a debt crisis or a debt service difficulty or default. Typically, the incidence of a debt crisis is interpreted as a debt rescheduling agreement or negotiation, arrears (amounts past due and unpaid) on principal repayments or interest payments and an upper-tranche IMF agreement.

Some papers use combinations of debt crisis definitions, others simply make use of single events or measurement of either debt rescheduling or arrears. For instance Berg and Sachs (1988), Lee (1991), Balkan (1992), Lanoie and Lemarbre (1996), and Marchesi (2003), have a common definition of a debt crisis using only the concept of debt rescheduling. All studies aim at picking out years in which countries reschedule their external debt. Broadly speaking, debt rescheduling is defined as a mechanism whereby the debtors offer the cred-

itors (commercial banks and governments of industrial countries) a revised contract that enables debtors not to default on their loans. The contract arrangements include an actual reduction of the principal and service of the debt and the postponement of payment. [4]

The approach of McFadden *et al.* (1985) and Hajivassiliou (1989,1994) comprises all three elements in their debt default definition. They consider the presence of arrears on interest or principal as an additional expression of a debt servicing problem. Overall, they define a country as experiencing a debt crisis in a given year if (i) there is an event of debt rescheduling with commercial or official creditors, (ii) an upper-tranche IMF agreement is underway, or (iii) the amount of accumulated arrears on interest payments or principal repayments exceeds some minimum threshold.

### 2.2 Indicators of financial crises

The empirical studies summarized in Table 1 share the idea that it is possible to identify a number of domestic and external macroeconomic fundamental indicators as the main determinants of a financial crisis. Some explanatory variables are exclusive for currency crises, banking crises or debt crises; others are informative for more than one type of crisis. The first two columns in the table list the indicator and a brief summary of its economic interpretation. The next three columns report the hypothesized sign of each indicator; a plus (minus) sign indicates that a high (low) value of the indicator reflects a high financial crisis probability. The final column list(s) the reference(s).

Seven variables are grouped as external sector indicators, five of which are related to the current account and two to the capital account. These variables are certainly affected not only by domestic economic conditions and policies, but also by global conditions such as fluctuations in the US dollar, international capital flows and commodity prices. The second group contains 16 indicators, nine financial indicators and seven domestic real-public variables (7 indicators) that are partly or fully driven by economic policy. Finally, three global indicators reflect major economic shifts in industrial countries and movements of oil prices which may trigger a crisis. Some indicators are multiple crises indicators in the sense that the same indicator hints at more than one type of financial crises. However, it is not sure whether such a multiple crises indicator affects the probability of two or more types of financial crises simultaneously, or whether it triggers one type of crisis which in turn rolls over to a second type of crisis, and a third. For instance, a drop in international competitiveness may result in a currency crises as a result of which a banking crises evolves. Our model allows for one indicator to affect two or more types of crises. However, the rollover effect is not captured explicitly.

4. Hajivassiliou (1987) and Li (1992) add the upper-tranche IMF agreement to their debt crisis definition. See IMF (2001) for details on the upper-tranche agreement.

Table 1: Explanatory variables: theory

| Indicator | Interpretation | CC | BC | DC | Reference(s) |
|---|---|---|---|---|---|
| *External sector (current account)* | | | | | |
| Real exchange rate | A measure for the change in international competitiveness and a proxy for over(under)valuation. Overvalued real exchange rate is expected to produce higher probability of financial crisis. | + | + | | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Kamin *et al.* (2001); Edison (2003); Dermirgüç-Kunt and Detragiache (2000); Eichengreen and Arteta (2000) |
| Export growth | An indicator for a loss of competitiveness in international good market. Declining export growth may be caused by an overvalued domestic currency and hence a proxy for currency overvaluation. On the other hand, if export growth slows due to reasons unrelated to the exchange rate, this may cause devaluation pressure. In both cases, declining export growth can be a leading indicator for a sizeable devaluation. | - | | - | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Edison (2003); Marchesi (2003) |
| Import growth | Weak external sector is part of currency crises. Enormous import growth could lead to worsening in the current account and have been often related with currency crises. | + | | | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Edison (2003) |
| Terms of trade | Increases in terms of trade should strengthen a country's balance of payments position and hence lower the probability of crisis. Terms of trade deteriorations may precede currency crisis. | - | - | - | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Kamin *et al.* (2001); Dermirgüç-Kunt and Detragiache (2000); Lanoie and Lemarbre (1996) |
| Ratio of the current account to GDP | A rise in this ratio is generally associated with large external capital inflows that are intermediated by the domestic financial system and could facilitate asset price and credit booms. Increases in the current account surplus are expected to indicate a diminished probability to devalue and thus to lower the probability of a crisis. | - | - | - | Berg and Pattillo (1999); Kamin *et al.* (2001); Eichengreen and Arteta (2000); Lanoie and Lemarbre (1996); Marchesi (2003) |
| *External sector (capital account)* | | | | | |
| Ratio of M2 to foreign exchange reserves | Captures to what extent the liabilities of the banking system are backed by foreign reserves. In the event of a currency crisis, individuals may rush to convert their domestic currency deposits into foreign currency, so that this ratio captures the ability of the central bank to meet their demands. | + | + | | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Kamin *et al.* (2001); Edison (2003); Dermirgüç-Kunt and Detragiache (2000); Eichengreen and Arteta (2000) |
| Growth of foreign exchange reserves | Declining foreign reserves is a reliable indicator that a currency is under devaluation pressure. A drop in reserves is not necessarily followed by devaluation, central bank may be successful in defending a peg, spending large amounts of reserves in the process. On the other hand, most currency collapses are preceded by a period of increased efforts to defend the exchange rate, which are marked by declining foreign reserves. Total value of foreign reserves are also used as indicators of a country's financial difficulty dealing with debt repayment. | - | | - | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Edison (2003); Marchesi (2003) |

*to be continued*

*(Table 1 continued)*

| Indicator | Interpretation | CC | BC | DC | Reference(s) |
|---|---|---|---|---|---|
| *Financial sector* | | | | | |
| M1 and M2 growth | These indicators are measures of liquidity. High growth of these indicators might indicate excess liquidity which may fuel speculative attacks on the currency thus leading to a currency crisis. | + | | | Kamin *et al.* (2001) |
| M2 money multiplier | An indicator associated with financial liberalization. Large increases in the money multiplier can be explained by draconian reductions in reserve requirements. | + | | | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Edison (2003) |
| Ratio of domestic credit to GDP | Very high growth of domestic credit may serve as a crude indicator of the fragility of the banking system. This ratio usually rises in the early phase of the banking crisis. It may be that as the crisis unfolds, the central bank may be injecting money to the bank to improve their financial situation. | + | + | | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Edison (2003); Dermirgüç-Kunt and Detragiache (2000); Eichengreen and Arteta (2000) |
| Excess real M1 balance | Loose monetary policy can lead to currency crisis. | + | | | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Edison (2003) |
| Domestic real interest rate | Real interest rate can be considered as proxy of financial liberalization, in which the liberalization process itself tends to lead to high real rates. High real interest rates signal a liquidity crunch or have been increased to fend off a speculative attack. | + | + | | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Edison (2003); Dermirgüç-Kunt and Detragiache (2000) |
| Lending and deposit rate spread | An increase of this indicator above some threshold level possibly reflects a deterioration in credit risk as banks are unwilling to lend or decline in loan quality. | + | | | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Edison (2003) |
| Commercial bank deposits | Domestic bank run and capital flight occur as crisis unfolds. | - | | | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Edison (2003) |
| Ratio of bank reserves to bank assets | Adverse macroeconomic shocks are less likely to lead to crises in countries where the banking system is liquid. | | | - | Dermirgüç-Kunt and Detragiache (1997) |
| *Domestic real and public sector* | | | | | |
| Ratio of fiscal balance to GDP | Higher deficits are expected to raise the probability of crisis, since the deficits increase the vulnerability to shocks and investor's confidence. | | | + | Dermirgüç-Kunt and Detragiache (2000); Eichengreen and Arteta (2000) |
| Ratio of public debt to GDP | Higher indebtedness is expected to raise vulnerability to a reversal in capital inflows and hence to raise the probability of a crisis. | + | + | + | Kamin *et al.*, (2001); Lanoie and Lemarbre (1996); Eichengreen and Arteta (2000) |
| Growth of industrial production | Recessions often precede financial crises. | - | | | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Edison (2003) |
| Changes in stock prices | Burst of asset price bubbles often precede financial crises. | - | | | Kaminsky *et al.* (1998); Berg and Pattillo (1999); Edison (2003) |

*to be continued*

*(Table 1 continued)*

| Indicator | Interpretation | CC | BC | DC | Reference(s) |
|---|---|---|---|---|---|
| *Domestic real and public sector continued* | | | | | |
| Inflation rate | The inflation rate is likely to be associated with high nominal interest rates and may proxy macroeconomic mismanagement which adversely affects the economy and the banking system. | | + | + | Dermirgüç-Kunt and Detragiache (1997); Lanoie and Lemarbre (1996); Marchesi (2003) |
| GDP per capita | High income countries may be less likely to reschedule their debt than poorer countries since the costs of rescheduling would tend to be more onerous for more advanced economies. Deterioration of the domestic economic activity are expected to increase the likelihood of a banking crisis. | | - | - | Dermirgüç-Kunt and Detragiache (1997); Eichengreen and Arteta (2000); Lanoie and Lemarbre (1996); Marchesi (2003) |
| National saving growth | High national savings may be expected to lower the probability of debt rescheduling. | | | - | Lanoie and Lemarbre (1996) |
| *Global economy* | | | | | |
| Growth of world oil prices | High oil prices are associated with recessions. | + | | | Edison (2003) |
| US interest rate | International interest rate increases are often associated with capital outflows. | + | + | | Edison (2003); Kamin *et al.* (2001); Eichengreen and Arteta (2000) |
| OECD GDP growth | Higher foreign output growth should strengthen exports and thus reduce the probability of a crisis. | - | - | | Edison (2003); Kamin *et al.* (2001); Eichengreen and Arteta (2000) |

Notes: CC, BC and DC represent currency crisis, banking crisis, and debt crisis, respectively.
Positive (negative) expected sign means that a high (low) value of the indicator causes a higher probability of a crisis.

Table 2 gives an overview of the empirical results of most of the papers on financial crises. The empirical papers deal with single crises only and differ in the types of analysis: signal extraction models and qualitative response models. Also the time span and the frequency of the data and the number of countries included in the analysis differs. Some papers use a short time span and cover a lot of countries—especially Lanoie and Lemarbre (1996)—while others cover a longer time span at the expense of a smaller country coverage.

Berg and Pattillo (1999) and Edison (2003) use the same set of currency crisis indicators as Kaminsky *et al.* (1998) apart from global economy indicators which are included to capture external shocks. All studies show that real exchange rates, export growth, and the ratio of M2 to international reserves are the most important indicators to explain the probability of currency crises.

Dermirgüç-Kunt and Detragiache (2000) consider the role of macroeconomic variables, deposit insurance and law enforcement in determining the likelihood of banking failure. They observe that the risk of a banking crisis becomes higher the lower output growth and the higher inflation, the domestic real interest rate, the ratio of M2 to international reserve, and domestic credit per GDP. Eichengreen and Arteta (2000) find that domestic credit booms and government fiscal balance are strongly associated with banking crises.

The most recent study on the probability of debt crises, Marchesi (2003) concludes that none of the indicators listed in Table 2 is significant. This result is not supported by Lanoie and Lemarbre (1996). They observe that the lower the rate of growth of GDP per capita and the large external capital inflows, the higher the probability of debt rescheduling and debt crises.

Table 2: Explanatory variables: empirics

| Indicator | KLR(1998) CC | BP(1999) CC | KSS(2001) CC | E(2003) CC | DKD(2000) BC | EA(2000) BC | LL(1996) DC | M(2003) DC |
|---|---|---|---|---|---|---|---|---|
| *External sector (current account)* | | | | | | | | |
| Real exchange rate | ∗ | ∗ | ∗ | ∗ | ∘ | ∘ | | |
| Export growth | ∗ | ∗ | | ∗ | | | | ∘ |
| Import growth | ∘ | ∘ | | ∘ | | | | |
| Terms of trade | ∘ | ∘ | ∗ | | ∘ | | ∘ | |
| Ratio of the current account to GDP | | ∗ | ∗ | | | ∘ | ∗ | ∘ |
| *External sector (capital account)* | | | | | | | | |
| Ratio of M2 to foreign exchange reserves | ∗ | ∗ | ∗ | ∗ | ∗ | ∘ | | |
| Growth of foreign exchange reserves | ∘ | ∗ | | ∘ | | | | ∘ |
| *Financial sector* | | | | | | | | |
| M1 and M2 growth | | | ∗ | | | | | |
| M2 money multiplier | ∘ | ∘ | | ∘ | | | | |
| Ratio of domestic credit to GDP | ∘ | ∘ | | ∘ | ∗ | ∗ | | |
| Excess real M1 balance | ∘ | ∘ | | ∘ | | | | |
| Domestic real interest rate | ∘ | ∘ | | ∘ | ∗ | | | |
| Lending and deposit rate spread | ∘ | ∘ | | ∘ | | | | |
| Commercial bank deposits | ∘ | ∘ | | ∘ | | | | |
| Ratio of bank reserves to bank assets | | | | | ∘ | | | |
| *Domestic real and public sector* | | | | | | | | |
| Ratio of fiscal balance to GDP | | | | | ∘ | ∗ | | |
| Ratio of public debt to GDP | | | ∗ | | | ∘ | ∘ | |
| Growth of industrial production | ∗ | ∘ | | ∘ | | | | |
| Changes in stock prices | ∗ | ∘ | | ∘ | | | | |
| Inflation rates | | | | | ∗ | | ∘ | ∘ |
| GDP per capita | | | | | ∗ | ∘ | ∗ | ∘ |
| National saving growth | | | | | | | ∘ | |
| *Global economy* | | | | | | | | |
| Growth of world oil prices | | | | ∘ | | | | |
| US interest rate | | | ∗ | ∘ | | ∘ | | |
| OECD GDP growth | | | ∗ | ∘ | | ∘ | | |
| Observations | 1970-1995 | 1970-1996 | 1981-1999 | 1970-1999 | 1980-1995 | 1975-1997 | 1989-1990 | 1983-1996 |
| Frequency | monthly | monthly | monthly | monthly | annual | annual | annual | annual |
| Method | Signal | Probit | Probit | Signal | Logit | Probit | Probit | Probit |
| Country coverage | 20 | 23 | 26 | 28 | 65 | 78 | 93 | 87 |

Notes: CC, BC and DC represent currency crisis, banking crisis, and debt crisis, respectively.

The mark ∘ and ∗ denote insignificant and significant indicators, respectively. The papers included in this table are KLR: Kaminsky, Lizondo and Reinhart (1998); BP: Berg and Pattillo (1999); KSS: Kamin, Schindler and Samuel (2001); E: Edison (2003); DKD: Dermirgüç-Kunt and Detragiache (2000); EA: Eichengreen and Arteta (2000); LL: Lanoie and Lemarbre (1996); M: Marchesi (2003).

## 3. Dating financial crisis

### 3.1 Currency crises

In this paper, we identify episodes of currency crisis in East Asia using four methods. In the first method, we adopt the complete concept of Eichengreen, Rose and Wyplosz (1995) in the construction of our exchange rate market pressure index. For the dating of currency crises we set the exchange market pressure index threshold to two standard deviations from the mean.[5] The results of this method are compared to three alternative methods: without country reference (based on Kaminsky, Lizondo and Reinhart, 1998), excluding unsuccessful attacks (as proposed by Frankel and Rose, 1996), and time-varying thresholds (following Zhang, 2001). Details are provided below.

**Currency crises dating, method ERW**

Eichengreen *et al.* assume that a speculative attack only exists in the form of extreme pressure in the foreign exchange market, which usually results in a devaluation (or revaluation), or a change in the exchange rate system, *i.e.* to float, fix or widen the band of the exchange rate. However, speculative attacks on exchange rates can also be unsuccessful. When facing pressure on its currency, the authorities have the option to raise interest rates or to run down international reserves. Hence, speculative pressure is measured by an index that is a weighted average of normalized changes in the exchange rate, the ratio of gross international reserves to M1, and the nominal interest rates. All variables are relative to a reference country, for which a country is selected with a strong currency that serves as an anchor to other countries. We use the US as our reference country. The index of exchange rate pressure is defined as follows:

$$EMPI_{i,t} = \frac{1}{\sigma_e}\frac{\Delta e_{i,t}}{e_{i,t}} - \frac{1}{\sigma_r}\left(\frac{\Delta rm_{i,t}}{rm_{i,t}} - \frac{\Delta rm_{US,t}}{rm_{US,t}}\right) + \frac{1}{\sigma_i}\Delta\left(i_{i,t} - i_{US,t}\right), \tag{1}$$

where $EMPI_{i,t}$ is the exchange rate market pressure index for country $i$ in period $t$; $e_{i,t}$ the units of country $i$'s currency per US dollars in period $t$; $rm_{i,t}$ the ratio of gross foreign reserves to $M1$ for country $i$ in period $t$, $i_{i,t}$ the nominal interest rates for country $i$ in period $t$; $i_{US,t}$ the nominal interest rates for the reference country (US) in period $t$; $\sigma_e$ the standard deviation of the relative change in the exchange rate $\left(\Delta e_{i,t}/e_{i,t}\right)$, $\sigma_r$ is the standard deviation of the difference between the relative changes in the ratio of foreign reserves and money ($M1$) in country $i$ and the reference country (US) $\left(\left(\Delta r_{i,t}/r_{i,t}\right) - \left(\Delta rm_{US,t}/rm_{US,t}\right)\right)$, and $\sigma_i$ the standard deviation of the nominal interest rate differential $\Delta(i_{i,t} - i_{US,t})$.

This measure is intuitively appealing. In case of speculative pressure, the index captures changes in the domestic exchange rate if the attack is successful and changes in international reserves or nominal interest rates if the speculative attack does not lead to a deval-

5. See Lestano and Jacobs (2002) for a sensitivity analysis of the dating scheme to different values of the threshold. Moreover, threshold models are also sensitive to the time period considered (see also Dungey *et al.*, 2003).

uation. A period of speculative attack is identified when the index exceeds some upper bound:

$$Crisis = \begin{cases} 1 \text{ if } EMPI_{i,t} > \beta\sigma_{EMPI} + \mu_{EMPI} \\ 0 \text{ otherwise,} \end{cases}$$

where $\sigma_{EMPI}$ equals the sample standard deviation of *EMPI* and $\mu_{EMPI}$ is the sample mean of *EMPI*. We arbitrarily set a threshold of $\beta = 2$, *i.e.* two standard deviations above the mean.

**Currency crises dating, method KLR**

Kaminsky, Lizondo and Reinhart (1998) modify the exchange market pressure index of Equation (1) by dropping the links to the reference country and multiplying the right-hand-side by the standard deviation of the relative change in the exchange rate:

$$EMPI_{i,t} = \frac{\Delta e_{i,t}}{e_{i,t}} - \frac{\sigma_e}{\sigma_r}\frac{\Delta r_{i,t}}{r_{i,t}} + \frac{\sigma_e}{\sigma_i}\Delta i_{i,t}, \tag{2}$$

where $EMPI_{i,t}$ is again the exchange rate market pressure index for country $i$ in period $t$ , $e_{i,t}$ the units of country $i$'s currency per US dollars in period $t$, $r_{i,t}$ gross foreign reserves of country $i$ in period $t$, $i_{i,t}$ the nominal interest rates for country i in period t, $\sigma_e$ the standard deviation of the relative change in the exchange rate $\Delta e_{i,t}/e_{i,t}$, $\sigma_r$ the standard deviation of the relative change in the reserves $\left(\Delta r_{i,t}/r_{i,t}\right)$, and $\sigma_i$ the standard deviation of the change in the nominal interest rate $\Delta i_{i,t}$.

To avoid the problem that currency crises are associated with high inflation, the sample is split into periods with hyperinflation and low inflation; separate indexes are constructed for each subsample. Contrary to their implementation, we include interest rates from the index. The definition of a currency crisis is the same as in ERW.

**Currency crises dating, method FR**

Frankel and Rose (1996) exclude unsuccessful speculative attacks from the exchange rate pressure concept. In their opinion international reserves are too rough a proxy to measure policy actions in defense of the currency. In addition, they argue that raising interest rates and exhausting international reserves is not standard practice to deal with speculative attack in most of the developing countries.

Our implementation of the Frankel and Rose (1996) method uses only nominal exchange rate variables and defines a currency crash as a nominal depreciation of the currency of at least 25 percent which is accompanied by an increase in the rate of depreciation of at least a 10 percent. The latter cut-off point is used to avoid registering periods with high inflation, which are usually followed by high depreciation. So, a currency crash is defined as

$$Crisis = \begin{cases} 1 \text{ if } \%\Delta e_{i,t} > 25\% \text{ and } \%\Delta e_{i,t} > 10\% + \%\Delta e_{i,t-1} \\ 0 \text{ otherwise} \end{cases} \tag{3}$$

**Currency crises dating, method Z**

Zhang (2001) criticized Eichengreen *et al.*'s exchange market pressure by pointing at two problems. First, changes in international reserves and interest rates may cancel against each other if the speculative attack is successful. For example, a positive change in the exchange rate (in anticipation of a devaluation) may trigger a fall in the interest rate and an increase in international reserves. Secondly, movements in international reserves and exchange rate can be volatile in some periods and relatively tranquil in other periods. Thus, an event that results in high volatility dominates the whole sample.

To tackle both problems, Zhang suggested decomposing Eichengreen *et al.*'s exchange rate market pressure index into its components and to use time-varying thresholds for each component. Zhang (2001) excludes interest rate variables and also drops the link to the reference country. However, we retain the interest rate differential in our index.

$$Crisis = \begin{cases} 1 \text{ if } \begin{cases} \Delta e_{i,t}/e_{i,t} > \beta_1 \sigma_{e,t} + \mu_{e,t} \text{ or} \\ \Delta r_{i,t}/r_{i,t} < \beta_2 \sigma_{r,t} + \mu_{r,t} \text{ or} \\ \Delta i_{i,t} > \beta_3 \sigma_{i,t} + \mu_{i,t} \end{cases} \\ 0 \text{ otherwise} \end{cases} \tag{4}$$

where $e_{i,t}$ = units of country $i$ currency per U.S. dollars at period $t$, $r_{i,t}$ = ratio of gross foreign reserves to M1 for country $i$ at period $t$, $i_{i,t}$ = interest rates for country $i$ at period $t$, $\sigma_{e,t}$ = standard deviation of $\left(\Delta e_{i,t}/e_{i,t}\right)$ in the sample of $(t-36, t-1)$, $\sigma_{r,t}$ = standard deviation of $\left(\Delta r_{i,t}/r_{i,t}\right)$ in the sample of $(t-36, t-1)$, and $\sigma_{i,t}$ = standard deviation of $\Delta i_{i,t}$ in the sample of $(t-36, t-1)$. We arbitrarily set the thresholds to $\beta_1 = \beta_3 = 2$ and $\beta_2 = -2$.

### 3.2 Banking crises

The list of banking crisis events provided by Kaminsky and Reinhart (1999) is very comprehensive in terms of providing information of banking crises on a monthly basis. Nevertheless, we use additional sources to complete our entire sample from January 1970 to December 2001, and also to include countries that are not covered in Kaminsky and Reinhart (1999), *i.e.* Singapore and South Korea. To date additional events, we rely heavily on the correspondence with central banks, IMF country reports and various financial publications. Table 3 provides information on the East Asia banking crisis dates and gives a brief description of the events.

Table 3: Banking crisis events

| Country | Date | Event |
|---|---|---|
| Indonesia | November 1992 | A large bank (Bank Summa) collapses and triggers runs on three smaller banks. |
| | November 1997 | The government liquidated 16 commercial banks. |
| | December 1997 | Bank of Indonesia (central bank) supports commercial bank liquidity amounted 5 % of GDP. |
| | January 1998 | The government guaranteed all customer deposit both in private and state banks, except for international banks. |
| | April 1998 | The government closed seven private national banks: Bank Surya, Bank Subentra, Bank Istismarat, Bank Pelita, Bank Hokindo, Bank Deka, dan Bank Centris. |
| | May 1998 | Bank Central Asia is taken over by the government. Bank Nusa Internasional, Bank Angkasa, and Bank Nasional Komersial merged with Bank Nasional. |
| | August 1998 | The government closed three private national banks: Bank Umum Nasional, Bank Modern, dan Bank Dagang Nasional Indonesia. At the same time, the government took over three private banks : Bank Danamon, Bank Central Asia, Bank PDFCI, dan Bank Tiara Asia. Three private banks, Bank Jaya International, Bank Artamedia and Bank Ciputra, merged with Bank Mashill. |
| | October 1998 | Four government-owned banks, Bank Dagang Negara, Bank Bumi Daya, Bank Pembangunan Indonesia, and Bank Exim, were merged into Bank Mandiri (new entity). |
| | March 1999 | The government closed 38 private national banks. |
| | June 2000 | Bank Danamon merged with 8 other private national banks. |
| | October 2000 | The government closed two national private banks, Bank Prasidha Utama and Bank Ratu. |
| | September 2002 | The government merged five national banks: Bank Bali, Bank Universal, Bank Patriot, Bank Prima Express, and Bank Artha Media. |
| Malaysia | July 1985 | Runs against some branches of a large domestic bank, following the collapse of a related bank in Hongkong. |
| | September 1998 | Bank Bumiputra Berhad merged with Commerce Asset Holding (Bank of Commerce). |
| | November 1998 | Merger between Perwire Affin Bank and BSN Commercial Bank. |
| | February 1999 | Merger between (i) Bank of Commerce and Bank Bumiputra, and (ii) Danamodal Nasional Investment with Arab Malaysian Bank, Arab-Malaysian Merchant Bank, BSN Commercial Bank, and Oriental Bank. |
| | July 1999 | Ban Hin Lee Bank merged with Southern Bank. |
| | August 1999 | 15 finance companies have been merged. |
| | December 2000 | 54 banks were merged into ten groups. |
| Philippines | January 1981 | Commercial paper market collapse, triggering bank runs and the failure on non-bank financial institutions and thrift banks. |
| | July 1985 | One commercial bank was closed. |
| | October 1998 | One commercial bank was closed. |

*to be continued*

*(Table 3 continued)*

| Country | Date | Event |
|---|---|---|
| | December 1998 | Philippine Bank of Communications merged with Asian Bank Corporation. |
| | March 1999 | One small commercial bank (the Prime Savings Bank) was closed on account of bankruptcy. |
| | May 1999 | the PCI Bank merged with Equitable Banking Corporation. |
| | October 1999 | Bank of the Philippine Islands and Far East Bank merged to become the largest bank in the country. |
| | April 2000 | Urban Bank was closed by the authorities. |
| Thailand | January 1979 | Following the stock market crash, one of the largest companies failed. The bail-out of the financial sector began. |
| | October 1983 | Large losses in a finance company lead to runs and government intervention. |
| | July 1997 | 42 financial companies suspended. |
| | June 1997 | Significant consolidation in the financial sector. Seven banks have been merged and bailed-out. |
| | November 1997 | 56 finance companies were closed. |
| | August 1998 | Union Bank was integrated with Krungthai Thanakit. First Bangkok City Bank was integrated with Krung Thai Bank. Laem Thong Bank is integrated with Radanasin Bank and privatized. |
| | April 1999 | Union Bank was integrated with twelve finance companies. |
| | December 2000 | Further consolidation in the financial sector. |
| | March 2002 | Siam City Bank and Bangkok Metropolitan Bank are merged. |
| | December 2002 | One financial company (Thanapat Credit Foncier) is closed. |
| South Korea | January 1997 | Monetary authority introduced a insurance deposit which fully covered all deposit not exceeding 20 million Won per depositor. |
| | September 1997 | Central bank provide liquidity support to merchant banks and Korean First Bank. |
| | November 1997 | The government announces that it guarantees all foreign liabilities of financial institutions, and provides liquidity to support private banks. |
| | December 1997 | Further liquidity support to commercial banks and other financial institutions. Two commercial banks, Korean First Bank and Seoul Bank, were taken over by government. |
| | January 1998 | The government closed 10 insolvent merchant banks. |
| | July 1998 | Five small banks with negative capital ratios were closed by the government. |
| | August 1998 | Merger between Boram Bank and Hana Bank Merger, and between Commercial Bank of Korea and Hanil Bank. |
| | September 1998 | Merger between Kookmin Bank and Long-term Credit Bank and between Boram Bank and Hana Bank. |
| | December 1998 | Merger between Kangwon Bank and Cho Hung Bank. |
| | January 1999 | Merger of undercapitalized banks, Commercial Bank and Hanil Bank, into large government-owned bank, Hanvit Bank. |
| | May 1999 | Merger between Cho Hung Bank and Chung Bak Bank |
| | August 1999 | 242 non-bank financial institutions in weak financial conditions had to stop their operations as ordered by the government. |
| Singapore | July 98 | Post Office Savings Bank merged with DBS Bank. |
| | August 1998 | Tat Lee Bank merged with Keppel Bank. |

### 3.3 Debt crises

Since World Bank data on interest and principal arrears are on an annual basis, we concentrated on debt rescheduling events for our debt crisis dating.

Table 4: Debt rescheduling events

| Country | Date | Rescheduling type |
|---|---|---|
| Indonesia | December 1966 | Official and non-official debt are rescheduled at the appropriate market rate with a repayment profile negotiated on a case-by-case basis. |
| | October 1967 | Idem |
| | October 1968 | Idem |
| | April 1970 | Idem |
| | June 1998 | Agreement on a framework for restructuring USD 80.23 billion of private debt. |
| | September 1998 | Treatment of maturities falling due from August 06, 1998 up to March 31, 2000. |
| | April 2000 | Non-official debt are rescheduled at the appropriate market rate over around 15 years with 2-3 years grace and progressive payments raising year by year. Official debt are rescheduled at an interest rate at least as favorable as the original concessional interest rate applying to these loans, over 20 years with a maximum 10-year grace. Repayment terms also include the possibility for creditor countries to conduct, on a bilateral and voluntary basis, debt swaps with the debtor country. |
| | April 2002 | Idem |
| Philippines | December 1984 | Debt rescheduling amounted USD 936 million. |
| | May 1985 | Commercial debt rescheduling amounted USD 5,885 million. |
| | January 1986 | Idem |
| | January 1987 | Debt restructuring with USD 988 million consolidation amount. |
| | December 1987 | Debt rescheduling amounted USD 9,010 million. |
| | May 1989 | Debt restructuring with USD 1,642 million consolidation amount. |
| | January 1990 | Debt rescheduling amounted USD 1,337 million of buy back at a 50 percent discount. |
| | February 1990 | Debt restructuring with USD 781 million consolidation amount. |
| | June 1991 | Debt restructuring with USD 1,682 million consolidation amount. |
| | July 1992 | Following implementation of a cash buy back of USD 1,3 billion on May, 1992. |
| | December 1992 | Following implementation of a cash buy back of USD 1,3 billion on May, 1992. |
| | July 1994 | Debt restructuring with USD 586 million consolidation amount. |
| | September 1996 | Voluntary debt swap. |
| | October 1999 | Voluntary debt swap. |
| South Korea | January 1998 | Restructuring the short-term foreign debts owed foreign commercial banks. |

The debt default refers to the condition that a country pursues commercial bank rescheduling with commercial borrowers as defined by the IMF and the World Bank. Commercial borrowers are defined as those developing countries for which at least one third of foreign borrowing is from private sector creditors. In this study, we also included debt problems that led to rescheduling of the official debt in the Paris Club,[6] debt equity swap and voluntary buybacks. Table 4 lists debt rescheduling events in our sample. No debt crises occur in Malaysia, Singapore and Thailand.

### 3.4 Financial crises: distribution over countries and time

Table 5 summarizes the distribution of the financial crises over the countries in our sample of six Asian countries. Currency crises are distributed more or less evenly over the six countries. Banking crises are relative rare for Singapore, a country with a more advanced banking system. Debt crises occur most frequently in Philippines, Indonesia coming second. With respect to the currency crisis definitions, the FR method signals most currency crises (nearly 35% of the months for all countries). ERW and KLR produce more or less the same number of currency crises (around 2.5% of the months). Zhang's definition with time-varying thresholds produces nearly 4 times as much currency crises as ERW and KLR.

Table 5: Financial crises: distribution over countries

| | Currency crises | | | | | |
|---|---|---|---|---|---|---|
| | ERW | KLR | FR | Z | Banking crises | Debt crises |
| Indonesia | 10 (2.60%) | 9 (2.34%) | 110 (28.65%) | 44 (11.46%) | 11 (2.86%) | 4 (1.04%) |
| Malaysia | 10 (2.60%) | 10 (2.60%) | 156 (40.63%) | 31 (8.07%) | 7 (1.82%) | 0 (0.00%) |
| Philippines | 10 (2.60%) | 12 (3.13%) | 141 (36.72%) | 52 (13.54%) | 8 (2.08%) | 14 (3.65%) |
| Singapore | 14 (3.65%) | 11 (2.86%) | 162 (42.19%) | 33 (8.59%) | 2 (0.52%) | 0 (0.00%) |
| South Korea | 7 (1.82%) | 7 (1.82%) | 121 (31.51%) | 27 (7.03%) | 12 (3.13%) | 1 (0.26%) |
| Thailand | 9 (2.34%) | 9 (2.34%) | 111 (28.91%) | 22 (5.73%) | 8 (2.08%) | 0 (0.00%) |
| All countries | 60 (2.60%) | 58 (2.52%) | 801 (34.77%) | 209 (9.07%) | 48 (2.08%) | 19 (0.82%) |

Notes: ERW, KLR, FR, and Z represent currency crises dated by the method of Eichengreen, Rose and Wyplosz, Kaminsky, Lizondo and Reinhart, Frankel and Rose, and Zhang, respectively.
The number between parentheses shows the frequency of crisis occurrence which is calculated by dividing the total number of crisis months by the total number of observations.

Figures 1 and 2 show the distribution of the financial crises for each country. Currency crises for all countries tend to be evenly distributed over time. Episodes of banking crises occur more frequently during 1990s, probably due to the intensive financial liberalization

6. The Paris Club is an informal group of official creditors (19 countries) whose role is to find co-ordinated and sustainable solutions to the payment difficulties experienced by debtor nations. Paris Club creditors agree to rescheduling debts due to them. Rescheduling is a means of providing a country with debt relief through a postponement and, in the case of concessional rescheduling, a reduction in debt service obligations (see http://www.clubdeparis.org/en/).

Table 6: Financial crises: distribution over the months of the year

| | Currency crises | | | | | |
|---|---|---|---|---|---|---|
| | ERW | KLR | FR | Z | Banking crises | Debt crises |
| January | 18 | 9 | 68 | 23 | 6 | 4 |
| February | 3 | 3 | 71 | 14 | 1 | 1 |
| March | 4 | 3 | 59 | 19 | 2 | 0 |
| April | 0 | 1 | 78 | 12 | 3 | 2 |
| May | 3 | 2 | 57 | 10 | 3 | 2 |
| June | 2 | 3 | 64 | 14 | 2 | 2 |
| July | 6 | 7 | 69 | 18 | 6 | 2 |
| August | 3 | 5 | 69 | 21 | 6 | 0 |
| September | 5 | 6 | 65 | 17 | 3 | 2 |
| October | 7 | 7 | 64 | 17 | 5 | 1 |
| November | 2 | 5 | 72 | 19 | 5 | 0 |
| December | 7 | 7 | 65 | 25 | 6 | 3 |
| Total | 60 | 58 | 801 | 209 | 48 | 19 |

Notes: ERW, KLR, FR, and Z represent currency crises dated by the method of Eichengreen, Rose and Wyplosz, Kaminsky, Lizondo and Reinhart, Frankel and Rose, and Zhang, respectively.

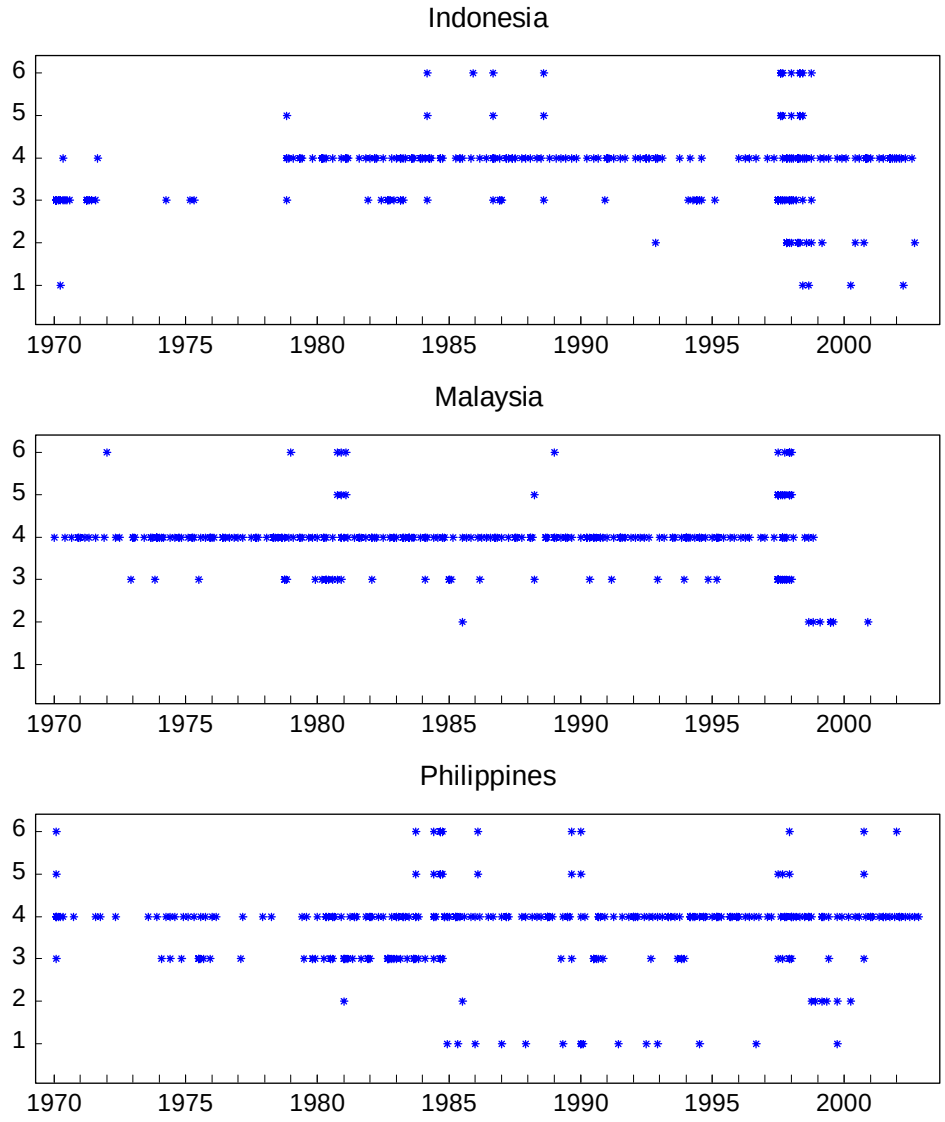
in these economies in the 1980s. As noted, Malaysia, Singapore and Thailand did not experience debt crises. For the other three countries, debt repayment difficulties became more frequent after currency and banking crises hit these countries during the 1990s.

Table 6 lists the distribution of the financial crises over the months of the year. There seems to be a January-effect in the financial crises data. January has the maximum number of crisis observations for ERW, KLR, bank and debt crises. Below we will test if this type of time effect is picked up in the estimations.

Since each method adopts a different definition of exchange rate market pressure, judging which dating system identifies currency crises is best is not trivial.[7] Therefore we include all currency crises dating schemes in our EWS.

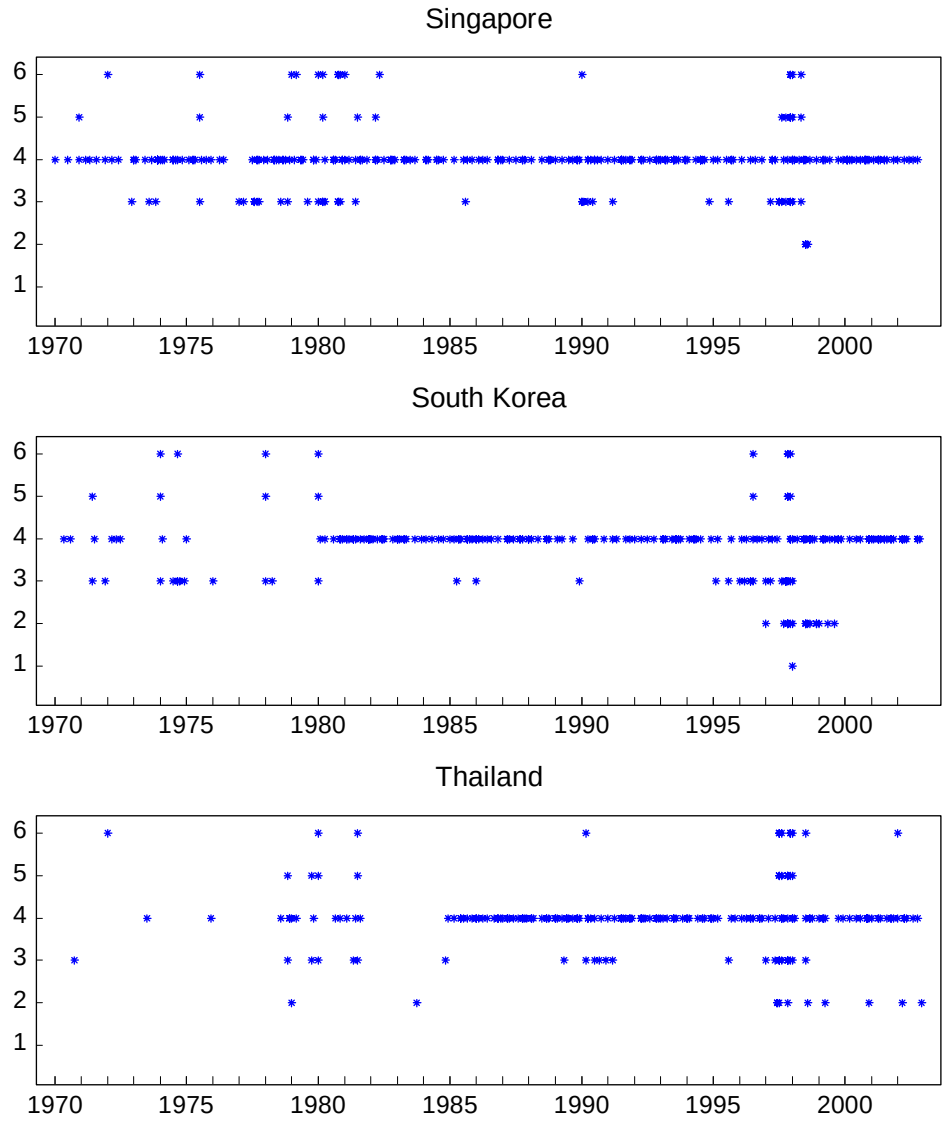
7. Edison (2003) and Kamin, Schindler, and Samuel (2001) reach a similar conclusion.

Figure 1: Financial crises in Indonesia, Malaysia and Philippines: distribution over time




Note: 6 stands for currency crisis (Eichengreen, Rose and Wyplosz); 5 currency crisis (Kaminsky, Lizondo and Reinhart); 4 currency crisis (Frankel and Rose); 3 currency crisis (Zhang); 2 banking crises; and 1 debt crisis.

Figure 2: Financial crises in Singapore, South Korea and Thailand: distribution over time




Notes: 6 stands for currency crisis method ERW; 5 currency crisis method KLR; 4 currency crisis method FR; 3 currency crisis method Z; 2 banking crises; and 1 debt crisis.

## 4. Estimation results

As already mentioned in the introduction, the aim of this paper is to construct a model that calculates the probability of a financial crisis. To do so we use a binomial multivariate qualitative response approach. The set of economic indicators that may contain information on whether or not a crises will occur is huge (cf. Table 1). It is not feasible to include all indicators in the logit model, so first we reduce the information set into a limited number of factors using factor analysis. These factors are then used as explanatory variables in the logit model.

### 4.1 Factor analysis

Technically speaking, factor analysis transforms a set of random variables linearly and orthogonally into new random variables.[8] The first factor is the normalized linear combination of the original set of random variables with maximum variance; The second factor is the normalized linear combination with maximum variance of all linear combinations uncorrelated with the first factor; and so on. By construction factors are uncorrelated. The eigenvalue for a given factor measures the variance in all the variables which is accounted for by that factor. If a factor has a low eigenvalue, then it may be ignored. Other factors are more important in explaining the variances in the set of variables under consideration. Because the factors often do not have economic meaning we cluster the indicators into four groups and perform factor analysis to each of the groups separately. The downside of this method is that it is not ruled out that factors from different groups are correlated.

There is no ”best” criterion for dropping the least important factors. The so-called Kaiser criterion drops all factors with eigenvalues below one. The Cattell scree test is a graphical method in which the eigenvalues are plotted on the vertical axis and the factors on the horizontal axis. The test suggests to select the number of factors that corresponds to the place of the curve where the smooth decrease of eigenvalues appears to level off to the right of the plot. In this paper we—in principal—use the scree test, but do not want too large a number of factors because of the problem of multicollinearity discussed above.

The main source of all data is the International Financial Statistics of the IMF for the macroeconomic and financial indicators and the World Bank Development Indicators for the debt variables. We use monthly data, covering six Asian countries, Indonesia, Malaysia, Philippines, Singapore, South Korea and Thailand, from January 1977 to the end of 2001. Missing data are supplemented from Advance/Datastream and various reports of the country’s central bank. All data in local currency units are converted into US dollars. Some annual indicators are interpolated to obtain a complete monthly database.

This study focuses on indicators of macroeconomic development and external shocks. Worsening of these indicators affects the stability of financial system and may result in a financial crisis. As noted in Section 2, the indicators are selected by theoretical consid-

8. For a detailed exposition of factor analysis including references see *e.g.*, Venables and Ripley (2002, Chapter 11).

eration as well as recent findings of empirical studies on financial crises. Another major consideration was the data availability on a monthly basis for our country coverage and sample. The indicators can be clustered into four major groups:

*External*: real exchange rates (REX), export growth (EXG), import growth (IMP), terms of trade (TOT), ratio of the current account to GDP (CAY), the ratio of M2 to foreign exchange reserves (MFR) and growth of foreign exchange reserves (GFR).

*Financial*: M1 and M2 growth (GM1 and GM2), M2 money multiplier (MMM), the ratio of domestic credit to GDP (DCY), excess real M1 balances (ERM), domestic real interest rate (RIR), lending and deposit rate spread (LDS), commercial bank deposits (CBD), and the ratio of bank reserves to bank assets (RRA).

*Domestic (real and public)*: the ratio of fiscal balance to GDP (FBY), the ratio of public debt to GDP (FBY), growth of industrial production (GIP), changes in stock prices (CSP), inflation rate (INR), GDP per capita (YPC), and growth of national saving (NSR).

*Global*: growth of world oil prices (WOP), US interest rate (USI), and OECD GDP growth (ICY).

Table 7 lists definitions, sources and transformations of our crises indicators. Two types of transformation are applied to make sure that the indicators are free from seasonal effects and stationary, *i.e.* 12-months percentage change and deviation from linear trends. In case the indicator has no visible seasonal pattern and is nontrending, its level form is maintained. Some unavailable indicators are proxied by closely related indicators, for example OECD GDP is substituted by industrial production of industrial countries.

As already argued, we cannot include the full set of 26 indicators as explanatory variables in our logit model, because of too few observations on some of the financial crises and multicollinearity among the indicators. Instead we summarize the information in a limited number of factors. Factor analysis on the full set applying the scree plot criterion described above results in a small number of orthogonal factors, which do not have a straightforward economic meaning.[9] Therefore we calculate factors for each group of indicators. The scree plot criterion in our case results in one or two factors for each group. More information is given below.

9. Note that if we apply the standard Kaiser criterion of eigenvalues larger than one on the full set of 26 indicators, we obtain eight factors and the economic interpretation is even harder.

Table 7: Explanatory variables: definition, source, and transformation

| Indicator | Code | Definition and source | Transformation |
|---|---|---|---|
| *External sector (current account)* | | | |
| Real exchange rate | REX | Nominal exchange rate is local currency unit (LCU) per USD, IFS-AE. The CPI is IFS-64. The real exchange rate is the ratio of foreign (US CPI) to domestic prices (measured in the same currency). Thus, REX = $eP_f/P$, where $e$ = nominal exchange rate, $P$ = domestic price (CPI), and $P_f$ = foreign price (US CPI). A decline in the real exchange rate denotes a real appreciation of the LCU. | Deviation from trend |
| Export growth | EXG | IFS-70.D | 12 month percentage change |
| Import growth | IMP | IFS-71.D | 12 month percentage change) |
| Terms of trade | TOT | Unit value of exports divided by the unit value of imports. Unit value of exports is IFS-74.D. Import unit value for country (IFS-75.D) is not available, instead exports prices of industrialized countries is used, IFS-110.74.D. | 12 month percentage change |
| Ratio of the current account to GDP | CAY | Current account (IFS-78AL) divided by nominal GDP (interpolated of IFS-99B). | - |
| *External sector (capital account)* | | | |
| Ratio of M2 to foreign exchange reserves | MFR | Ratio of M2 (IFS-34 plus IFS-35) and international reserves (IFS-1L.D). M2 is converted into USD. | 12 month percentage change |
| Growth of foreign exchange reserves | GFR | IFS-1L.D | 12 month percentage change |
| *Financial sector* | | | |
| M1 growth | GM1 | IFS-34 | 12 month percentage change |
| M2 growth | GM2 | IFS-35 | 12 month percentage change |
| M2 money multiplier | MMM | Ratio of M2 (IFS-34 plus IFS-35) to base (reserve) money (IFS-14). | 12 month percentage change |
| Ratio of domestic credit to GDP | DCY | Total domestic credit (IFS-32) divided by nominal GDP (interpolated of IFS-99B). | 12 month percentage change |
| Excess real M1 balance | ERM | Percentage difference between M1 (IFS-34) deflated by CPI (IFS-64) and estimated demand for M1. Demand for real M1 is estimated as function of real GDP, nominal interest rates (IFS-60L), and a time trend. If monthly real GDP data is not available for a country, then its annual counterpart (IFS-99BP) is interpolated to monthly data. | Based on estimated money demand equation |
| Domestic real interest rate | RIR | 6 month time deposit (IFS- 60L) deflated by CPI (IFS-64) | - |
| Lending and deposit rate spread | LDS | Lending interest rate (IFS-60P) divided by 6 month time deposit rate (IFS-60L) | - |
| Commercial bank deposits | CBD | Demand deposit (IFS-24) plus time, savings and foreign currency deposits (IFS-25) deflated by CPI (IFS-64) | 12 month percentage change |
| Ratio bank reserves to bank assets | RRA | Bank reserves (IFS-20) divided by bank assets (IFS-21 plus IFS-22a to IFS-22f) | - |

*to be continued*

*(Table 7 continued)*

| Indicator | Code | Definition and source | Transformation |
|---|---|---|---|
| *Domestic real and public sector* | | | |
| Ratio of fiscal balance to GDP | FBY | Government budget balance (IFS-80) divided by nominal GDP (interpolated IFS-99B). | - |
| Ratio of public debt to GDP | PBY | Public and publicly guaranteed debt (World Bank) divided by nominal GDP (interpolated IFS-99B). | - |
| Growth of industrial production | GIP | Industrial production index for Country is not available, then index of primary production (crude petroleum, IFS.66AA) is used | 12 month percentage change |
| Changes in stock prices | CSP | IFS-62 | 12 month percentage change |
| Inflation rate | INR | IFS-64. | 12 month percentage change |
| GDP per capita | YPC | GDP (interpolated IFS-99B) divided by total population (interpolated IFS-99Z). | 12 month percentage change |
| National savings | NSR | public (IFS-91F) and private consumption (IFS-96F) subtracted from GDP (interpolated IFS-99B). | 12 month percentage change |
| *Global economy* | | | |
| Growth of world oil prices | WOP | IFS-176.AA | 12 month percentage change |
| US interest rate | USI | US treasury bill rate (IFS-111.60C) | 12 month percentage change |
| OECD GDP growth | ICY | Proxied by industrial production (IFS-66). | 12 month percentage change |

A disadvantage of factor analysis applied to groups of indicators is the fact that the factors need not be orthogonal any more. The correlation between the factor of the group of financial indicators and the factor of the group of the domestic (real and public) indicators is around 0.7 with a huge influence on the logit parameter estimates. So, we apply factor analysis on the combined group. Two factors emerge, which are orthogonal by construction. In the end we identify five factors: two factors from the set of external indicators (explaining 47% of total variance of the group), two factors from the combined set of financial and domestic indicators (explaining 39% of total variance of the group) and one factor in the group of global indicators (explaining 55% of total variance of the group). Corresponding scree plots are in Figure 3.

Figure 3: Scree plots

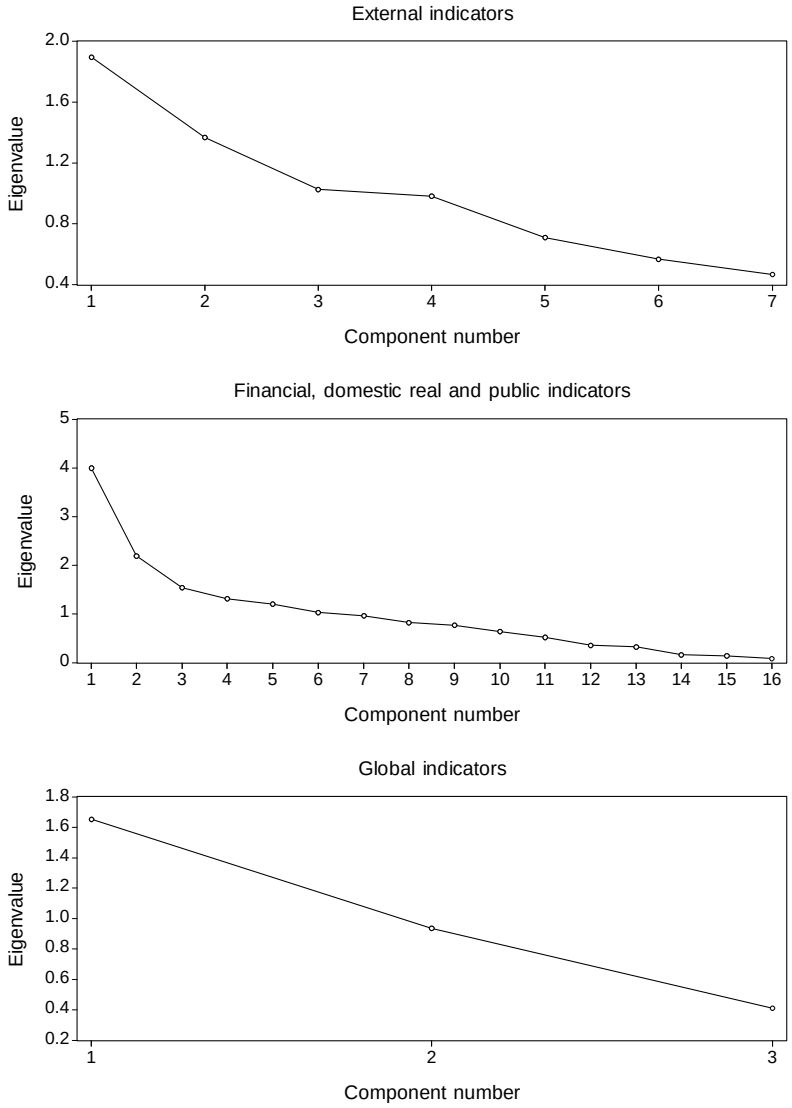


Table 8: Correlation between factors and indicators and the proportion of the variance explained by the factors ($h^2$)

| | *External* | | | *Financial & Domestic* | | | *Global* |
|---|---|---|---|---|---|---|---|
| | factor 1 | factor 2 | | factor 3 | factor 4 | | factor 5 |
| REX | 0.00 | 0.33 | GM1 | 0.90 | 0.00 | WOP | 0.46 |
| EXG | 0.83 | −0.02 | GM2 | 0.93 | 0.04 | USI | 0.88 |
| IMP | 0.76 | −0.18 | MMM | −0.08 | −0.08 | ICY | 0.82 |
| TOT | 0.69 | −0.15 | DCY | −0.16 | 0.30 | | |
| CAY | −0.21 | 0.36 | ERM | 0.09 | 0.17 | | |
| MFR | −0.19 | −0.82 | RIR | −0.04 | 0.90 | | |
| GFR | 0.27 | 0.63 | LDS | −0.07 | −0.19 | | |
| | | | CBD | 0.71 | 0.46 | | |
| | | | RRA | 0.24 | −0.39 | | |
| | | | FBY | 0.02 | −0.06 | | |
| | | | PBY | −0.16 | −0.06 | | |
| | | | GIP | 0.35 | 0.07 | | |
| | | | CSP | 0.24 | 0.12 | | |
| | | | INR | −0.01 | −0.88 | | |
| | | | YPC | 0.90 | −0.17 | | |
| | | | NSR | 0.82 | −0.16 | | |
| $h^2$ | 0.27 | 0.20 | | 0.25 | 0.14 | | 0.55 |

The first two factors relate to external indicators. We observe that the first factor is driven by current account variables (export growth EXG, import growth IMP and terms of trade TOT) and the second factor captures variations of variables related to the capital account (the ratio of M2 and foreign reserves MFR, growth of international reserves GFR). The third and the fourth factor summarize financial and domestic indicators. The former corresponds to flows (in values or in rate of growth): money growth (GM1 and GM2), commercial bank deposits (CBD), GDP per capita (YPC) and the growth of national savings (NSR); the latter with prices: domestic real interest rates (RIR) and inflation (INR). The global factor, the fifth, captures variations in the US interest rate (USI) and OECD output growth (ICY).

Table 9 lists the correlation coefficients between our five factors in pairs. The first and second factor and the third and fourth factor are indeed not correlated. The maximum correlation between the factors is in the order of 0.5.

Table 9: Correlation between factors

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | | | | |
| 2 | 0.00 | | | |
| 3 | 0.47 | −0.06 | | |
| 4 | 0.40 | −0.01 | 0.00 | |
| 5 | 0.52 | 0.05 | 0.27 | 0.22 |

### 4.2 Logit model

Since our dependent variable is a binary variable (0=no crisis and 1=crisis) we use the logit model. Suppose the probability model is specified as

$$P = F(Z) = \frac{1}{1+e^{-Z}} = \frac{1}{1+e^{-(\alpha+\beta X)}}, \tag{5}$$

where $P$ is the probability that $Z$ takes the value 1 and $F$ is the cumulative logistic probability function; $X$ is the set of regressors and $\alpha$ and $\beta$ are parameters. It can be shown that the regression equation is equal to

$$\ln \frac{P}{1-P} = Z = \alpha + \beta X. \tag{6}$$

The vector of explanatory variables $X$ consists of the factors and not of the huge list of economic indicators themselves. Tests for fixed effects reject the null of common effects in five out of six cases. Only in FR's method of currency crises we tested for time (month) effects as well, but these where rejected. In the other cases the number of observations is insufficient to properly test for time effects, see Table 6 above.

The estimation results presented in Table 10 allow a number of conclusions. In the case of debt crises and Z-type currency crises model the null of common effects is not rejected at the 5% level: the common intercept in both cases is significant at 1%. In the other cases the null of common effects is rejected in favour of fixed effects. Fixed effects are all significant at the 1% level implying country-specific intercepts.

The main conclusion refers to the significance of the constructed factors. All factors, except the first one, are significant at the 5% level in at least one crises model:

*Factor 1 — related to growth of exports and imports and the terms of trade* — is not significant at 5% in any of the models.

*Factor 2 — related to the ratio of M2 to foreign reserves and the growth of foreign reserves* — is significant in the ERW-type, the KLR-type and the Z-type of currency crises models and also in the banking crises model.

*Factor 3 — related to money growth (M1 and M2), rates of growth of bank deposits, the*

*growth of GDP per capita and growth of domestic savings* — is significant in all models including all types of currency crises models.

*Factor 4 — related to the domestic real interest rate and inflation* — is significant in the KLR-type, the FR-type and also in the banking crises model.

*Factor 5 — related to the US interest rate and OECD output growth* — is significant in the ERW-type, the KLR-type and the Z-type of currency crises models.

When we compare the four versions of the currency crises models, differences in terms of significant factors come to the fore. The external sector plays an important role only through the capital account (factor2). Factor 3—money growth and bank deposits—appears in all currency models. Moreover the estimated coefficient for this factor is the highest in absolute terms in all currency models. Factor 2—the ratio of M2 to international reserves and growth of foreign reserves—enters all currency crisis models except the FR version. Factor 4—domestic real interest rate and inflation—is significant in the KLR and FR versions of currency models but does not show up in the ERW-type and Z-type currency models. Factor 5—US interest rate and OECD output growth— only matters in the ERW version, KLR version and Z version of the currency model. We have already noted that factor 1 (current account) does not matter for all financial crisis models. Banking crises are influenced by factor 2–4. Global indicators, factor 5, do not play a role here. Finally, indicators included in the third factor—money growth and bank deposits—seems to be the only relevant ones for debt crises.

Our results deviate from the theoretically expected ones as reported in Table 1 in a number of cases. First, in our models export and import growth, terms of trade and inflation rate do not influence debt crises. Secondly, the global indicators (US inflation rate and OECD output growth) and terms of trade do not have an impact on banking crises. Thirdly, currency crises are not amplified by the external sector indicators, terms of trade and growth of exports and imports.

However the estimation results in Table 10 are consistent with the empirical literature as summarized in Table 2. In our debt crises model, output per capita is strongly related to the probability of debt rescheduling. This result is in accordance with the findings of Lanoie and Lemarbre (1996). We find that the inflation rate, GDP per capita and the ratio of M2 to international reserves are significantly associated with banking crises. A similar result is found by Dermirgüç-Kunt and Detragiache (2000). The ratio of M2 over foreign reserves, a proxy for liquidity of the financial system, is an important determinant in our currency crises models, in line with Kaminsky, Lizondo, and Reinhart (1998), Berg and Pattillo (1999), and Edison (2003). In addition, we find support for the conclusion of Kamin, Schindler, and Samuel (2001) that other indicators like the growth of money (M1 and M2) and global indicators (US interest rates and OECD output growth) play a role in determining the onset of currency crises.

The models discussed above to do not consider lags in the various factors. Nor do the models account for any linkages between crises within and across countries. These extensions will be dealt with in future research.

Table 10: Estimation results of the multivariate binomial logit model including five factors.

| | Currency crises | | | | | |
|---|---|---|---|---|---|---|
| | ERW | | KLR | | FR | |
| | Coefficient | $z$-statistic | Coefficient | $z$-statistic | Coefficient | $z$-statistic |
| constant | | | | | | |
| Indonesia | −4.54 | −11.03 | −5.16 | −10.80 | −0.87 | −7.42 |
| Malaysia | −4.10 | −11.44 | −4.38 | −11.46 | −0.39 | −3.65 |
| Philippines | −4.53 | −11.51 | −4.64 | −11.95 | −0.62 | −5.47 |
| Singapore | −3.44 | −11.86 | −3.85 | −11.59 | −0.31 | −2.91 |
| South Korea | −4.45 | −10.70 | −4.79 | −10.63 | −0.73 | −6.54 |
| Thailand | −4.02 | −10.52 | −4.45 | −10.70 | −1.02 | −8.17 |
| factor 1 | −0.23 | −1.04 | −0.08 | −0.33 | 0.03 | 0.42 |
| factor 2 | −0.30 | −2.59 | −0.31 | −2.54 | 0.05 | 0.90 |
| factor 3 | −0.94 | −6.52 | −1.26 | −8.21 | −0.29 | −5.25 |
| factor 4 | −0.15 | −0.97 | −0.36 | −2.18 | −0.13 | −2.38 |
| factor 5 | 0.62 | 3.29 | 0.88 | 4.17 | −0.06 | −1.08 |
| Observations | | 60 | | 58 | | 801 |
| Likelihood ratio statistic | | 71.08 | | 108.70 | | 51.53 |
| McFadden $R^2$ | | 0.13 | | 0.20 | | 0.02 |

| | Currency crises | | | | | |
|---|---|---|---|---|---|---|
| | Z | | Banking crises | | Debt crises | |
| | Coefficient | $z$-statistic | Coefficient | $z$-statistic | Coefficient | $z$-statistic |
| constant | −2.46 | −30.12 | | | −5.08 | −18.43 |
| Indonesia | | | −4.32 | −10.23 | | |
| Malaysia | | | −4.34 | −10.34 | | |
| Philippines | | | −4.41 | −11.12 | | |
| Singapore | | | −5.59 | −7.68 | | |
| South Korea | | | −3.76 | −11.08 | | |
| Thailand | | | −4.90 | −11.10 | | |
| factor 1 | 0.18 | 1.72 | −0.39 | −1.32 | 0.37 | 1.60 |
| factor 2 | −0.40 | −6.19 | 0.68 | 3.34 | 0.19 | 0.86 |
| factor 3 | −0.60 | −7.10 | −0.54 | −3.51 | −0.57 | −2.56 |
| factor 4 | −0.14 | −1.72 | −0.47 | −2.28 | 0.22 | 1.14 |
| factor 5 | 0.17 | 1.92 | 0.18 | 0.83 | −0.26 | −0.93 |
| Observations | | 209 | | 48 | | 19 |
| Likelihood ratio statistic | | 81.37 | | 75.67 | | 15.84 |
| McFadden $R^2$ | | 0.06 | | 0.17 | | 0.07 |

Notes: ERW, KLR, FR, and Z denote currency crises dated by the method of Eichengreen, Rose and Wyplosz, Kaminsky, Lizondo and Reinhart, Frankel and Rose, and Zhang, respectively.

Critical values of the $Z$-statistic at the 1%, 5% and 10% level are 2.57, 1.86 and 1.65, respectively. The common effects model is rejected at the 5% level in all models, except the Z-version of the currency crisis model and the debt crisis model (DC). Time effects—if tested significantly—do not affect the factor parameter estimates and, hence, are not included.

In all cases, the likelihood ratio tests reject the hypothesis that the slope coefficients of the factors are all equal to zero at the 5% level (the critical value is 11.07).

### 4.3 Signaling crises

The logit models discussed above estimate probabilities of crises to occur. High probabilities signal crises. But the model might also give false signals, *i.e.*, a crisis does not take place despite the logit model producing a high probability. There are four possibilities. A model may indicate a crisis (high estimated probability) when a crisis indeed occurs ($P(1,1)$) or it may indicate a crisis when no crisis actually takes place ($P(1,0)$). It is also possible that the model does not signal a crisis (low estimated probability) where in fact a crisis does occur ($P(0,1)$). The final possibility ($P(0,0)$) is a situation in which the model does not predict a crisis and no crisis occurs. Table 11 lists the four possibilities.

Table 11: The probabilities of right and wrong crisis predictions

| | | Crisis ($Z=1$) | No crisis ($Z=0$) |
|---|---|---|---|
| Estimated probability | high | $P(1,1)$ | $P(1,0)$ |
| | low | $P(0,1) = 1 - P(1,1)$ | $P(0,0) = 1 - P(1,0)$ |

The model signals a crisis when the estimated probability is high. We calculate the probability in periods detected as crises as:

$$P(1,1) = \frac{\sum_t \hat{P}_t Z_t}{\sum_t Z_t}, \tag{7}$$

where $\hat{P}_t$ is the estimated probability from the logit model at time $t$ and $Z_t$ is the crisis index dummy which equals one if a crisis occurs at time $t$, and zero otherwise. The probability in periods not detected as crises is denoted as $P(1,0)$:

$$P(1,0) = \frac{\sum_t \hat{P}_t (1 - Z_t)}{\sum_t (1 - Z_t)} \tag{8}$$

This is a false signal or noise. Note that $P(0,1) = 1 - P(1,1)$ is also a false signal: the estimated probability is low, whereas a crisis did occur. Similarly, $P(0,0) = 1 - P(1,0)$ is a correct signal, since the estimated probability is low and there is no crisis.

Now, we can calculate the signal-to-noise ratio $S/N$ as a measure of performance of the model:

$$\frac{S}{N} = \frac{P(1,1) + P(0,0)}{P(1,0) + P(0,1)}. \tag{9}$$

A value below one indicates that the model gives more false than right signals. The higher the signal-to-noise ratio, the better the model performs. A number like 1.5 indicates that the model indicates a signal level which is 50% above the noise level.

Table 12 lists the good ($P(1,1)$) and bad ($P(1,0)$) crisis signals and the signal to noise ratio for the various types of financial crises and the six Asian countries in our sample. From the signal-to-noise ratio it is easily seen that the currency crisis models based on the

Table 12: Signalling crises instantaneously

| | | Currency crises | | | | | |
|---|---|---|---|---|---|---|---|
| | | ERW | KLR | FR | Z | Banking crises | Debt crises |
| Indonesia | $P(1, 1)$ | 0.13 | 0.19 | 0.34 | 0.14 | 0.25 | 0.10 |
| | $P(1, 0)$ | 0.02 | 0.02 | 0.27 | 0.09 | 0.02 | 0.01 |
| | S/N | 1.25 | 1.40 | 1.15 | 1.09 | 1.58 | 1.21 |
| Malaysia | $P(1, 1)$ | 0.08 | 0.12 | 0.40 | 0.12 | 0.04 | – |
| | $P(1, 0)$ | 0.02 | 0.02 | 0.41 | 0.09 | 0.02 | 0.01 |
| | S/N | 1.12 | 1.20 | 0.99 | 1.05 | 1.05 | – |
| Philippines | $P(1, 1)$ | 0.11 | 0.14 | 0.38 | 0.18 | 0.02 | 0.01 |
| | $P(1, 0)$ | 0.02 | 0.03 | 0.36 | 0.11 | 0.02 | 0.01 |
| | S/N | 1.19 | 1.24 | 1.03 | 1.16 | 1.00 | 1.00 |
| Singapore | $P(1, 1)$ | 0.05 | 0.07 | 0.42 | 0.08 | 0.03 | – |
| | $P(1, 0)$ | 0.04 | 0.03 | 0.42 | 0.08 | 0.01 | 0.01 |
| | S/N | 1.03 | 1.08 | 1.01 | 1.01 | 1.05 | – |
| South Korea | $P(1, 1)$ | 0.08 | 0.12 | 0.34 | 0.16 | 0.16 | 0.02 |
| | $P(1, 0)$ | 0.02 | 0.02 | 0.30 | 0.09 | 0.03 | 0.01 |
| | S/N | 1.14 | 1.22 | 1.09 | 1.15 | 1.30 | 1.02 |
| Thailand | $P(1, 1)$ | 0.13 | 0.22 | 0.30 | 0.12 | 0.05 | – |
| | $P(1, 0)$ | 0.02 | 0.02 | 0.29 | 0.06 | 0.02 | 0.01 |
| | S/N | 1.25 | 1.49 | 1.02 | 1.12 | 1.05 | – |

Notes: ERW, KLR, FR, and Z represent currency crises dated by the method of Eichengreen, Rose and Wyplosz, Kaminsky, Lizondo and Reinhart, Frankel and Rose, and Zhang, respectively.
$P(1, 1)$=the estimated probability is high and a crisis does occur; $P(1, 0)$=the estimated probability is high and a crisis does not occur; S/N is the signal-to-noise ratio; — means no crisis observations.

dating methodology of Kaminsky, Lizondo and Reinhart (KLR) and Eichengreen, Rose and Wyplosz (ERW) outperform the other models.

Table 12 calculates the signal-to-noise ratios when a model signals a crisis in the same month as the crisis occurs. However, the models may signal a crisis which actually happens in the near future. Table 13 calculates the signal-to-noise ratios in cases where the model leads future crises with the lead ranging from zero (as in Table 12) to four quarters.

Table 13: Signal-to-noise ratio for various leads of the crisis index

| | | Currency crises | | | | | |
|---|---|---|---|---|---|---|---|
| | Lead | ERW | KLR | FR | Z | Banking crises | Debt crises |
| Indonesia | 0 | 1.25 | 1.40 | 1.15 | 1.09 | 1.58 | 1.21 |
| | 1 | 1.23 | 1.22 | 1.15 | 1.06 | 1.42 | 1.16 |
| | 2 | 1.20 | 1.19 | 1.14 | 1.05 | 1.58 | 1.16 |
| | 3 | 1.23 | 1.22 | 1.13 | 1.03 | 1.76 | 1.15 |
| | 4 | 1.22 | 1.24 | 1.11 | 1.02 | 1.56 | 1.14 |
| Malaysia | 0 | 1.12 | 1.20 | 0.99 | 1.05 | 1.05 | – |
| | 1 | 1.06 | 1.09 | 1.00 | 1.02 | 1.06 | – |
| | 2 | 1.04 | 1.05 | 0.98 | 1.01 | 1.07 | – |
| | 3 | 1.02 | 1.02 | 0.99 | 1.00 | 1.10 | – |
| | 4 | 1.00 | 0.99 | 0.98 | 0.99 | 1.10 | – |
| Philippines | 0 | 1.19 | 1.24 | 1.03 | 1.16 | 1.00 | 1.00 |
| | 1 | 1.11 | 1.11 | 1.03 | 1.13 | 0.99 | 1.00 |
| | 2 | 1.05 | 1.03 | 1.01 | 1.09 | 1.01 | 1.00 |
| | 3 | 1.05 | 1.03 | 1.00 | 1.07 | 1.00 | 1.00 |
| | 4 | 1.03 | 1.01 | 1.00 | 1.07 | 1.01 | 1.00 |
| Singapore | 0 | 1.03 | 1.08 | 1.01 | 1.01 | 1.05 | – |
| | 1 | 1.01 | 1.03 | 1.02 | 0.99 | 1.05 | – |
| | 2 | 1.01 | 1.02 | 1.00 | 0.99 | 1.05 | – |
| | 3 | 1.00 | 1.01 | 1.00 | 0.99 | 1.03 | – |
| | 4 | 1.01 | 1.03 | 1.00 | 0.99 | 1.02 | – |
| South Korea | 0 | 1.14 | 1.22 | 1.09 | 1.15 | 1.30 | 1.02 |
| | 1 | 1.03 | 1.04 | 1.10 | 1.10 | 1.27 | 1.03 |
| | 2 | 1.00 | 1.00 | 1.08 | 1.05 | 1.27 | 1.01 |
| | 3 | 1.00 | 0.99 | 1.08 | 1.02 | 1.30 | 1.00 |
| | 4 | 1.00 | 0.99 | 1.07 | 1.01 | 1.31 | 1.00 |
| Thailand | 0 | 1.25 | 1.49 | 1.02 | 1.12 | 1.05 | – |
| | 1 | 1.20 | 1.32 | 1.04 | 1.09 | 1.04 | – |
| | 2 | 1.15 | 1.21 | 1.02 | 1.07 | 1.05 | – |
| | 3 | 1.11 | 1.15 | 1.02 | 1.06 | 1.04 | – |
| | 4 | 1.09 | 1.11 | 1.03 | 1.05 | 1.03 | – |

Notes: ERW, KLR, FR, and Z represent currency crises dated by the method of Eichengreen, Rose and Wyplosz, Kaminsky, Lizondo and Reinhart, Frankel and Rose, and Zhang, respectively.

— means no crisis observations.

Table 13 allow a number of conclusions. The previous finding that the currency crises model based on the dating methodology of Kaminsky, Lizondo and Reinhart (KLR) and Eichengreen, Rose and Wyplosz (ERW) outperforms the other currency crisis methods remains valid. In general, the further away the future crises, the lower the signal-to-noise ratios. There are exceptions: the Frankel and Rose type of currency crisis model (FR) produces the best signal for currency crises one quarter ahead, whereas for the other types of currency crisis methods the signal is strongest for contemporaneous crises. For most countries considered the banking crises models produce the best signal for crises two or three quarters ahead. Comparing country performance, currency crisis models do a poor job in signalling crises for Singapore. Banking crises and debt crises models have a good performance in terms of the signal-to-noise ratio for Indonesia.

Finally, we perform an out-of-sample experiment for the year 2002 for the six Asian countries in our sample. Table 14 presents some summary statistics. The top panel lists the number of crises detected by the various dating schemes, the bottom panel predicted probabilities. Frankel and Rose find the largest number of currency crises and indeed the average predicted probabilities are highest. In the previous in-sample experiment we identified the currency crises models based on the dating methodology of Kaminsky, Lizondo and Reinhart (KLR) and Eichengreen, Rose and Wyplosz (ERW) as the 'best'. These dating methods identify currency crises in the Philippines and in Thailand, both in January 2002. However, the estimated probabilities over the year 2002 for both methods never exceed 10%; currency crises are not picked up instantaneously.

Table 14: Predicted crisis probabilities for 2002

| | Currency crises | | | | | |
|---|---|---|---|---|---|---|
| | ERW | KLR | FR | Z | Banking crises | Debt crises |
| *Number of crises* | | | | | | |
| Indonesia | 0 | 0 | 5 | 0 | 1 | 1 |
| Malaysia | 0 | 0 | 0 | 0 | 0 | 0 |
| Philippines | 1 | 0 | 6 | 0 | 0 | 0 |
| Singapore | 0 | 0 | 5 | 0 | 0 | 0 |
| South Korea | 0 | 0 | 5 | 0 | 0 | 0 |
| Thailand | 1 | 0 | 5 | 0 | 2 | 0 |
| *Predicted probabilities* | | | | | | |
| Mean | 0.023 | 0.016 | 0.382 | 0.108 | 0.015 | 0.008 |
| Median | 0.014 | 0.007 | 0.359 | 0.075 | 0.012 | 0.007 |
| Maximum | 0.091 | 0.079 | 0.554 | 0.357 | 0.039 | 0.018 |
| Minimum | 0.000 | 0.000 | 0.206 | 0.011 | 0.001 | 0.003 |
| Std. dev. | 0.022 | 0.019 | 0.095 | 0.086 | 0.011 | 0.003 |

Note: ERW, KLR, FR, and Z represent currency crises dated by the method of Eichengreen, Rose and Wyplosz, Kaminsky, Lizondo and Reinhart, Frankel and Rose, and Zhang, respectively.

## 5. Conclusion

Financial crises incur large costs which makes the construction of a monitoring tool, the so-called *early warning system* (EWS) very important. A common feature of all existing EWS's is the use of fundamental determinants of the domestic and external sectors as explanatory variables. In the literature different types of models are suggested. The most popular one is qualitative response models (logit or probit).

This paper builds an econometric EWS of six Asian countries, Malaysia, Indonesia, Philippines, Singapore, South Korea, and Thailand. We set up qualitative choice—in our case logit—models for three categories of financial crises, currency crisis, banking crisis and debt crisis. From the literature we extract a broad set of potentially relevant financial crisis indicators which are combined using factor analysis. These factors are used as explanatory variables in a panel covering the period January 1970–December 2001.

The first two factors relate to external indicators. We observe that the first factor is driven by current account variables while the second factor captures variations of variables related to the capital account. The third and the fourth factor summarize financial and domestic indicators. The former correlates with flows (in values or in rates of growth); the latter with prices. The global factor, the fifth, captures variations in the US interest rate and OECD output growth.

The factor analysis outcomes in combination with the estimation results of the logit model allows the general conclusion that (some) indicators of financial crises do work, at least in our EWS of Asia. Our method offers a solution to the bad performance (mixed and weak in timing of crisis) of EWS as noted by Edison (2003). We find that the rates of growth of money (M1 and M2), bank deposits, GDP per capita and national savings correlate with all three types of financial crises, whereas the ratio of M2 to foreign reserves, and the growth of foreign reserves, the domestic real interest rate and inflation play an additional role in banking crises and some varieties of currency crises.

An additional feature of this paper is that we distinguish four currency crisis dating definitions. A within-sample signal extraction experiment revealed that the methods of Eichengreen, Rose and Wyplosz and Kaminsky, Lizondo and Reinhard are superior to the dating schemes of Frenkel and Rose, and Zhang.

There are differences in terms of factor significance when we compare the four versions of the currency crises models. Money growth and bank deposits are significant in all currency models. In addition the estimated coefficient for this factor is the highest in absolute terms in all currency models. Foreign reserves enter all currency models except the Frankel and Rose model. The domestic real interest rate and inflation only matter in the Kaminsky, Lizondo and Reinhard and the Frankel and Rose versions of the currency model. Global indicators are significant in all currency models except in the Frankel and Rose version. The current account indicators do not affect financial crises. The same holds for current account and the global indicators and banking crises. Only money growth and bank deposits seem to play a role the debt crises model.

Based on an in-sample experiment (signal-to-noise ratios) we conclude that the currency crises models based on the dating methodology of Kaminsky, Lizondo and Reinhart and Eichengreen, Rose and Wyplosz outperform the other models. In general, the further away the future crises, the lower the signal-to-noise ratios. However, the Frankel and Rose type of currency crises model signals crises one quarter ahead, whereas the other types of currency crises models signal crises without a lead. For most countries considered the banking crises models signal crises two or three quarters ahead. Comparing country performance, currency crises models do a poor job in signaling crises for Singapore. Banking crises and debt crises models have a good performance in signaling crises in Indonesia.

Finally, we performed an out-of-sample experiment for the year 2002. The dating methodology of Kaminsky, Lizondo and Reinhart and Eichengreen, Rose and Wyplosz identify currency crises in the Philippines and in Thailand, both in January 2002. However, our models fail to pick up these currency crises.

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